COATINGS. ENAMELS

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CHEMICAL RESISTANCE OF LOW-MELTING ENAMELS FOR DECORATING GLASS PRODUCTS

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The chemical resistance of lead-free low-melting opaque enamels intended for decorating the external surface of household glass is determined depending on the duration of treatment with hot (98°C) water and 2% sodium carbonate solution. The synthesized enamels can be attributed to the class of enamels resistant to hot water and weakly alkaline solutions.

The world production of glass (household glass, glass containers) keeps growing, the product range keeps expanding and service and decorative properties improve. One of the promising ways for decorating the exterior surface of glass items is using low-melting enamels. The resistance of enamel coatings to water and dish-washing detergents determine their long service life.

The purpose of our study is to determine the chemical resistance of opaque low-melting enamels intended for decorating the exterior surface of articles made of soda-lime glass.

Enamels were prepared on the basis of lead-free flux containing (wt.%): 10.0 SiO_2, 34.0 ZnO, 16.0 P_2O_5, 6.0 TiO_2, 1.5 Al_2O_3, 10.0 BaO, 10.0 B_2O_3, 1.0 CaO; $\Sigma R_2O = 11.5$ with the following physicochemical and technological properties: melting temperature 1000 – 1100°C, TCLE 85.5×10^{-7} K^{-1}, and softening temperature 478°C.

To obtain tinted enamels, pigments produced at the Dulevskii Paint Factory were added to the flux in the optimum amount of 5%. Enamel powder was produced by joint milling of the flux with corresponding pigments for 6 h in a planetary mill and separating the fraction below 40 μm.

The enamel slip containing (weight parts) 60 enamel powder, 27 2% alcohol solution of sodium-carboxymethyl cellulose 7MF, 12 water, 0.2 aerosil, and 0.8 0.1% solution of urea was prepared by mixing components in a ball mil for 1 h. Household glass samples were coated with slip by the spraying method. The obtained coatings were dried at room temperature for 30 min and fired in a muffle furnace with a 20 min exposure at 580°C.

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The chemical resistance of enamel coatings deposited on glass substrates was determined based on its behavior in hot (98°C) water and 2% solution of sodium carbonate at room temperature. After 1-h treatment with the specified reactants the samples were rinsed, dried, weighed, and then again immersed in the specified solutions. The total duration of the experiment was 5 h for all reactants. The quantity of the reactants was taken equal to 5 cm^3 per 1 cm^2 of the sample surface. The weight losses of the samples converted to 100 cm^2 of surface area coated with enamel was found from the formula:

$$a = \frac{A - B}{S} \times 100,$$

where A and B is the weight of the glass sample coated with enamel before and after the treatment, respectively, mg, and S is the surface area of the sample coated with enamel, cm^2.

The weight losses of samples with a nondecorated surface can be neglected for being insignificant and within measurement error bounds.

The surface structure of samples was investigated using a LEO 1420 scanning microscope with magnification × 6000. The spraying of a gold layer on the coating surface was performed on a VUP-2K vacuum spraying plant.

Figure 1 shows the chemical resistance of enamel coating of blue, green, and black colors to the specified chemical reactants depending on treatment duration. It can be seen that enamel coatings regardless of their color have low weight losses after hot water treatment. Visually, the coatings do not lose luster and do not change color. The weight loss of the blue, green, and blue coatings after 1-h hot water treatment was equal to 15.7, 16.0, and 17.1 mg/100 cm^2, respectively;

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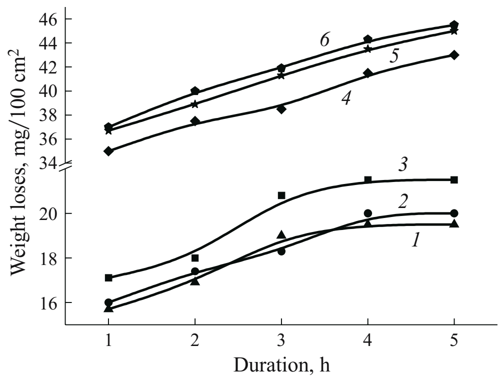

Fig. 1. Weight loses of enamel coating samples of blue (*1*, *4*), green (*2*, *5*), and black (*3*, *6*) colors converted to 100 cm^2 of enamel-coated surface depending on the duration of hot (98°C) water treatment (*1 – 3*) and 2% sodium carbonate solution (*4 – 6*).

after 5 h treatment — 19.5, 20.0, and 21.5 mg/100 cm^2. The process of dissolution of an enamel coating in hot water has a deceleration stage depending on the treatment duration, which is characterized by a curve segment transforming into a nearly straight line parallel to the abscissa axis. This can be attributed to the formation of a protective siliceous film [1].

A more intense destruction of experimental enamel coatings is observed after the effect of 2% sodium carbonate solution. Thus, the weight loss of the blue, green, and black coating after 1-h treatment in 2% sodium carbonate solution is equal to 35.0, 36.7, and 37.0 mg/100 cm^2, respectively and after 5 h — 43.0, 45.0, and 45.5 mg/100 cm^2, respectively. It should be noted that coatings exposed in 2% sodium carbonate solution for 5 h do not lose their luster and color. According to standard TU RB 100029049.030, the following requirements are imposed on enamels for decorating exterior surfaces of glass articles: admissible weight losses per 100 cm^2 of enamel coating after 1-h treatment in 2% sodium carbonate solution should be not more than 100 – 200 mg and in hot (98°C) distilled water not more than 50 – 100 mg.

Figure 2 shows the results of microscope analysis of variations in the blue surface coating depending on treatment with various reactants. The enamel coating before treatment has a smooth surface. The corrosion of the decorative surface under the effect of hot water or sodium carbonate is perceptibly different. The enamel coating gets destroyed more intensely in 2% sodium carbonate solution than in hot water.

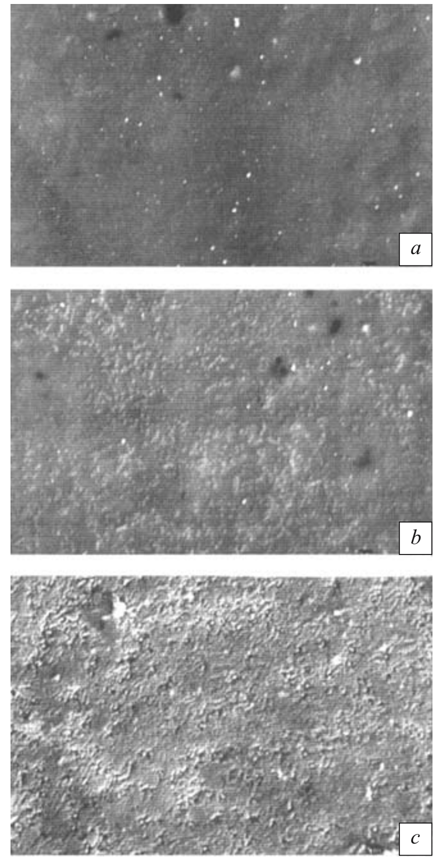

Fig. 2. Electron-microscope photos of blue enamel coating (× 6000): *a*) initial surface; *b*) surface after treatment for 5 h in hot (98°C) water; *c*) the same, 2% sodium carbonate solution at room temperature.

The studies performed have identified the quantitative transition of enamel from decorative coatings to solutions depending on treatment duration. Synthesized enamels are chemically resistant to hot water and to weakly alkaline solutions and can be recommended for decorating exterior surfaces of articles made of soda-lime glass.

REFERENCES

1. I. I. Kitaigorodskii, *Technology of Glass* [in Russian], Stroiizdat, Moscow (1967).